UNIVERSITY OF PENNSYLVANIA

A Comparative Study of Audito-Vocal Digit Spans

MARY H. YOUNG

A THESIS
IN PSYCHOLOGY

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
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Reprinted from
The Psychological Clinic, Vol. XVII, Nos. 6-7

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By Mary H. Young

R. UNIV. BIBLIOTHEEK LEIDEN

I. Historical Statement

A. forward digit span

Jacobs[1] in 1887 seems to have originated the use of the immediate reproduction of a series of letters, digits, words and other material as a mental test. Since that time many variations of his tests have been used.

The digit span test was employed in the original Binet-Simon[2] tests and has since been employed in the different revisions of the Binet by somewhat shifting the age norms. The Binet tests use the forward and backward reproduction of digits.

Humpstone[3] employed the group test method necessitating the immediate written reproduction of a series of digits presented at the rate of about 6 digits per 5 seconds at an even rate of speed. Standards were worked out for children ranging in age from 6 to 18 and for college men and women.

In the Psychological Clinic at the University of Pennsylvania, under the direction of Dr. Witmer, memory span tests have been employed for many years in all of the case studies.

According to Humpstone, Dr. A. L. Ide tested 1,900 boys and girls, using the auditory presentation of digits and considering the correct response in one out of three trials as the memory span score. In referring to this work Humpstone[4] states that Ide's averages for both age and grade are higher than those in his own study.

B. digit learning span test

In the use of the digit span test for diagnostic purposes, it was sometimes Dr. Witmer's practice to repeat a series of digits upon which a child had failed, in order to determine how many repetitions were required for the child to learn a series of digits one

[1] Jacobs, Joseph. *Experiments in Prehension. Mind*, 1887, vol. 12, pp. 75-79.

[2] Binet-Simon Tests. *L'Annee Psychologique.* 1905. xii, pp. 191-244.

[3] Humpstone, H. J. *Some Aspects of Memory Span. A Study in Associability.* Psychological Clinical Press, Philadelphia, Pennsylvania, 1917.

[4] *Ibid.*

greater than his digit span. This practice suggested to the writer the possibility of working out a standard procedure for determining what might be called the child's "learning span." This was first done in 1921 when the writer made a study of five hundred eighty-one children in Philadelphia.

C. REVERSE DIGIT SPAN TEST

The reverse digit span test is used in the Stanford Revision of the Binet Tests[5] from year 7 to year 18. Credit is given if one set out of three digit sets is repeated correctly. Anna S. Starr[6] in her survey considered the reverse digit span of importance in diagnosis, using two correct responses out of four as the reverse digit span score.

II. GROUPS STUDIED ON DIGIT SPAN IN PRESENT INVESTIGATION

1. In 1921-22 all children from 4 years and 0 months to 7 years and 11 months of age in two Philadelphia public schools were tested. This gave a total of 581 children.

2. In 1925 all the children of the Bloomington, Indiana Public Schools from 6 years, 0 months, to 10 years, 11 months of age were tested. The reverse digit span test was given only to this group. This gave a total of 1,179 children.

3. Philadelphia groups and Bloomington groups combined made a total of 1,760 cases.

III. PRELIMINARY WORK ON DIGIT SPAN PROCEDURE

Memory span or span of attention is an old test. It has been used in various ways by different authorities. Hence one of the first questions to settle in this study of digit span was that of the method to be employed. To do this a preliminary experiment was planned:

1. To decide when a subject's Digit Span had been obtained.

2. To determine the number of trials necessary to obtain a subject's Learning Span.

A random selection of 65 Primary grade boys and girls was made by the predetermined method of selecting alphabetically the first 13 children from the teacher's class roll in the following grades: kindergarten, 1A and 1B; 2A and 2B who were less than eight years old.

[5] TERMAN, LEWIS M. *The Measurement of Intelligence.* Cambridge, 1916.

[6] STARR, ANNA SPIESMAN. *The Diagnostic Value of the Audito-Vocal Digit Memory Span.* The Psychological Clinic, 1923, vol. 15, pp. 61-84.

These results were scored by two methods; that of counting one correct response out of two and that of counting one correct response out of three as indicating each child's digit span. Fifty-five percent of the cases made a score one higher by the latter plan. In more than half of these cases there would have been a difference of one digit more between the digit span and learning span by the first method, because a lower digit span would necessarily put the first learning span where the digit span fell according to the second method.

In order to decide the maximum number of trials which should be required of each child, so as to secure a trustworthy balance between economy of time, fairness to the child and reliability of learning span before rating him as "failed" on a given series, a preliminary study was made of 115 children.

A summary of the learning span results shows that of these 115 cases, 48 per cent after fifteen repetitions of the series were unable to demonstrate a learning span of one greater than their digit span; 52 per cent had a learning span at least one digit higher; only 7 per cent of these secured their learning spans within the last five of the fifteen trials, while 45 per cent of them secured their learning spans within the first ten trials.

The 52 per cent of the cases who succeeded in learning 1 digit above their Digit Spans. Only 12 cases or 10 per cent of the 115 succeeded in learning two digits beyond their digit spans. All these children did this on the fifth, sixth, seventh or eighth repetition. Since the cases of the entire group either learned two digits beyond ther digit spans within 8 trials or failed entirely after 15 trials it appears to have been a waste of time to have given any one more than 8 trials.

The evidence furnished by the children who learned one digit beyond their digit spans within 8 trials or failed entirely after 15 trials beyond their digit spans indicated that 10 trials would be sufficient to determine a child's learning span.

IV. Method of Procedure

A. Forward digit span:

The foregoing series of digits constitute the test material for the digit span test. When a child came for the test, the examiner said to him, "I am going to read some numbers. Listen carefully. When I stop, you are to say the numbers as I did. Listen to this one:" (Examiner gave series 3A, repeating the digits at the rate

Digit List F for Digit Span and Learning Span Tests

Series	Digits
2–A	9–1
B	2–5
C	3–7
3–A	4–9–7
B	1–6–3
C	5–8–1
4–A	8–2–6–4
B	7–4–2–9
C	6–2–8–4
5–A	4–1–8–6–3
B	6–2–9–4–7
C	8–3–5–1–9
6–A	7–2–4–9–5–3
B	8–1–5–9–2–7
C	3–1–9–4–2–6
7–A	6–9–3–7–1–5–8
B	2–6–8–4–1–7–5
C	4–2–8–6–1–3–7
8–A	1–4–7–2–9–6–3–8
B	7–1–3–5–8–4–6–9
C	4–8–1–6–2–9–7–3
9–A	3–7–5–2–8–6–4–9–1
B	5–7–3–9–6–1–4–8–2
C	6–2–9–4–7–1–5–3–8
10–A	9–2–7–4–1–6–9–3–5–8
B	4–7–1–3–8–6–2–9–7–3
C	9–4–1–6–8–3–5–7–2–4
11–A	2–8–4–2–6–4–9–1–7–5–3
B	9–2–5–8–3–6–1–4–7–9–5
C	2–7–4–9–1–6–3–8–5–1–7
12–A	1–9–6–2–4–8–1–5–7–3–1–8
B	4–9–1–7–4–2–8–6–3–9–5–1
C	6–4–9–2–5–8–3–6–1–9–7–3
13–A	5–8–2–6–9–4–7–1–3–8–5–2–7
B	3–6–8–1–7–9–6–4–1–9–2–4–8
C	6–1–4–8–2–5–9–3–7–5–1–8–3
14–A	8–4–6–2–9–7–4–2–8–6–3–9–5–7
B	2–6–9–4–7–1–5–8–2–5–9–3–6–1
C	7–5–9–2–6–8–1–4–6–2–9–7–4–1

DIGIT LIST R: FOR REVERSE DIGIT SPAN TESTS

Series	Digits
2–A	8–3
B	7–4
C	6–1
3–A	2–9–5
B	6–1–3
C	9–7–2
4–A	6–2–7–9
B	7–2–5–3
C	4–9–7–1
5–A	1–5–9–2–7
B	9–6–2–1–4
C	1–3–5–9–2
6–A	8–2–6–9–7–1
B	3–7–9–6–1–4
C	5–2–7–9–4–6
7–A	9–1–7–5–3–6–2
B	5–2–8–1–6–3–9
C	6–9–2–8–5–7–1
8–A	6–4–1–8–5–2–7–9
B	3–1–7–2–5–9–6–4
C	9–6–2–8–1–3–7–5
9–A	1–3–6–9–4–7–1–5–2
B	3–7–4–1–6–9–2–8–5
C	6–1–4–7–2–9–5–8–3
10–A	7–9–1–3–5–8–2–6–4–1
B	3–7–9–2–6–1–8–4–2–5
C	2–5–8–3–9–7–4–1–6–8

of six per five seconds) "4-9-7." If the child repeated these numbers correctly, the examiner proceeded to the next higher set of digits—that of 4A. If these were repeated correctly, the examiner gave the next higher set of digits, and so on, until the child failed to repeat one of the "A" series at a given level. In this event, he was given the "B" series of the same length, and if he failed on the "B" series, he was given the "C" series of the same length. Thus, in the case of failure, the child was given three trials on that length. His score was the number of digits in the longest series which he repeated correctly.

B. LEARNING SPAN TEST:

When the child failed the A, B, C series of a given length, the "C" series was repeated to him a second time immediately after he failed it, and was repeated a third time if he failed it on the second repetition,—and so on until he was able to repeat the series or had demonstrated his inability to do so after ten trials. If he succeeded on any of these trials, the next higher "A" series was given in the same manner until he gave it correctly or failed after ten trials. If he succeeded in any of these attempts, the next higher "A" series was presented. Thus, the successive "A" series were repeated until one was reached where the child failed on ten trials. The longest series of digits learned on ten or less trials was taken as the learning span.

C. REVERSE DIGIT SPAN TEST:

Immediately after the digit span and the learning span had been obtained, the reverse span was secured in the following manner:

The examiner said to the child, "I am going to read some more numbers. This time you must say them backwards. Suppose I said, '1-9' and you were to say it backwards, you would say '9-1.' Now you listen to these numbers and say them backwards." The examiner then turned to Digit List R and read Series 2-A. If the child did not get the concept of reversing the digits, the examiner told him the correct response. The child was then given Series 2-B and if he failed the correct response, it was given again. Finally the Series 2-C was read and in the event of failure, the child was again told the correct response. If he failed on this, he was given the 3-B, and then the 3-C. If he failed these three series, his memory span was marked zero. If, however, he repeated any one of the series of two digits correctly, and failed all series of three digits, he was credited with a reverse digit span of two. If the child succeeded with the 3-A, B or C series, the examiner next read the 4-A series, and so on in the manner of the method of procedure for giving the digit memory span. In this way, each set of series of equal length was presented to the child until he failed all three, that is, the A, B and C series of the same length. The largest number of digits a child repeated backwards correctly was taken as the reverse digit span.

It is to be noted that the examiner must form the habit of saying the digits at the uniform rate of six in five seconds, in a monotonous tone of voice, without rhythm or grouping. Only

TABLE 1—AGE-GRADE DISTRIBUTION OF CASES

Age	Grade							Total
	K	I	II	III	IV	V	VI	
4	53							53
5	98	20						118
6	11	358	24	1				394
7		192	236	35	4			467
8		21	92	111	27			251
9		4	24	74	121	21	1	245
10		1	13	24	73	98	23	232
Total	162	596	389	245	225	119	24	1760

TABLE 2—DIGIT SPAN GRADE DISTRIBUTIONS OF CASES

D.S.	Grade							Totals
	K	I	II	III	IV	V	VI	
2	0	2						2
3	33	53	2		1			89
4	88	209	63	26	12	2		400
5	31	229	192	99	99	38	4	692
6	9	85	100	67	60	37	12	370
7	1	17	27	46	34	23	7	155
8	0	1	4	6	16	13	1	41
9	0		1	1	3	6		11
Totals	162	596	389	245	225	119	24	1760

TABLE 3—DISTRIBUTION OF CASES ACCORDING TO THE AMOUNT EACH LEARNING SPAN EXCEEDED ITS RESPECTIVE DIGIT SPAN

D.S.	Excess of L.S. over D.S.										Total	Ave.
	0	1	2	3	4	5	6	7	8	9		
2		2									2	1.00
3	37	46	5					1			89	.72
4	141	222	35	2							400	.75
5	237	374	71	7	2				1		692	.73
6	157	150	53	8	1					1	370	.70
7	65	65	22	2					1		155	.80
8	18	15	8								41	.75
9	6	5									11	.45
Total	661	879	194	19	3	0	0	1	2	1	1760	

TABLE 4—DIGIT SPAN—REVERSE DIGIT SPAN DISTRIBUTION OF CASES

D.S.	Reverse Digit Span							Ave. R.Span.	No. of Cases
	0	2	3	4	5	6	7		
2	2							0	2
3	27	7	2		1			.7	37
4	69	51	81	16				1.9	217
5	14	61	253	101	13		1	3.0	443
6	10	21	138	85	26	3		3.3	283
7	1	8	64	54	18			3.5	145
8	1		7	20	9	4		4.1	41
9			1	7	3			4.2	11
Totals	124	148	546	283	70	7	1	2.9	1179

TABLE 5—DIGIT SPAN DISTRIBUTIONS ACCORDING TO GRADE WITHIN AGE

D.S.	4 years	5 years		6 years				7 years				8 years				9 years						10 years				
	K	K	I	K	I	II	III	I	II	III	IV	I	II	III	IV	I	II	III	IV	V	VI	II	III	IV	V	VI
2					1			1																		
3	12	19	1	2	31			18				3	2													
4	30	51	7	7	122	2		68	32	1	1	9	23	11		2	3	11	4			3	3	7	2	
5	10	20	10	1	134	8		81	124	11	1	3	39	45	11	1	12	32	55	6	1	10	11	32	32	4
6	1	8	2		55	9		22	62	15		5	20	29	5	1	8	16	33	6		1	7	22	31	11
7				1	14	3	1	2	18	7		1	5	22	6		1	13	20	4			3	8	19	7
8					1	1				1	1		3	5	4			1	7	4				4	9	1
9						1					1						1		2	1					5	

TABLE 6—REVERSE SPAN-AGE-GRADE DISTRIBUTION OF CASES

R.D.S.	*6 years*				*7 years*					*8 years*					*9 years*							*10 years*					
	I	II	III	Total cases	I	II	III	IV	Total cases	I	II	III	IV	Total cases	I	II	III	IV	V	VI	Total cases	II	III	IV	V	VI	Total
0	83	1		84	33	1	1		35	7	2			9	1						1						
2	55	0		55	33	22	11		66	6	15	7		28	2	4	1	1			8	4					4
3	34	15	1	50	22	102	9		133	7	60	73	8	148	1	18	46	53	5		123	7	17	37	24	2	87
4	2	3		5	3	12	1	3	19	1	15	28	15	59		2	24	54	10		90	3	7	28	53	7	98
5	0	1		1		2	0	1	3			4	4	8			2	13	4	1	20			8	19	10	37
6																			2		2				2	3	5
7																										1	1

such assistance as is mentioned in the directions for giving the test should be offered, if results are to be comparable. Examiners must be careful not to give hints to the child by habits of lip movements or attitudes suggesting the correct digit. A moderate amount of encouragement without giving away the correct response is desirable and permissible.

Summary of Results

I. The mode in digit span for 4 and 5 year old children is 4 digits; for 6, 7, 8, 9, and 10 year old children is 5 digits and for all children irrespective of age is 5 digits.

II. The average digit span for 4 and 5 year old children is 4 digits; for 6 and 7 year olds is 5 digits; for 8, 9, and 10 years approximately 6 digits; and for the entire group is 5 digits.

III. Learning span in relation to Digit Span.

Of all children with a Digit Span of 3, 58 per cent earned learning spans;
Of all children with a Digit Span of 4, 64 per cent earned learning spans;
Of all children with a Digit Span of 5, 65 per cent earned learning spans;
Of all children with a Digit Span of 6, 58 per cent earned learning spans;
Of all children with a Digit Span of 7, 54 per cent earned learning spans;
Of all children with a Digit Span of 8, 52 per cent earned learning spans;
Of all children with a Digit Span of 9, 46 per cent earned learning spans.

Irrespective of digit span 38 per cent of the cases were incapable of learning beyond their digit spans; 50 per cent of the cases made a learning span of 1 digit greater than their digit spans; 11 per cent, a learning span of 2; and 1 per cent of the cases gained a learning span of 3 digits greater than their digit spans. Here and there were found a few scattered cases capable of getting a learning span of 6, 7, or 8 digits above that of their original digit span.

IV. The average learning span for all digit span groups having 8, 9 or more cases per group was less than 1 digit above their digit span.

V. The following summary aids in interpreting a child's digit span performance if he is compared with his proper age group.

Age Yrs.	*Min.*	*Max.*	*Med.*	*Mode*	*60 Per Cent Mode*
4	3	6	4	4	3-4-5
5	3	6	4	4	4-5
6	2	9	5	5	4-5
7	2	9	5	5	5-6
8	3	8	5	5	5-6
9	4	9	5	5	5-6
10	4	9	6	5	5-6

TABLE 7—PERCENTAGES OF SUPERIORITY-INFERIORITY—DIGITS SPAN FOR EACH AGE

D.S.	*4 years*	*5 years*	*6 years*	*7 years*	*8 years*	*9 years*	*10 years*
2			0.2> 0 <99.8	0.2> 0 <99.8			
3	23> 0<77	17> 0<83	0.2> 8 <93	4 > 0.2<96	3> 0<97		
4	56>23<21	49>17<34	34 > 9 <57	22 > 4 <74	18> 3<79	8> 0<92	6> 0<94
5	19>79< 2	25>66< 9	36 >43 <21	46 >26 <28	39>21<40	43> 8<49	39> 6<55
6	2>98< 0	9>91< 0	16 >79 < 5	22 >72 < 6	23>60<17	27>51<22	31>45<24
7			5 >94 < .6	6 >94 < .6	13>83< 4	16>78< 6	16>76< 8
8			.4>99 < .2	.4>99 < .2	4>96< 0	4>94< 2	6>92< 2
9			.2>98.8< 0	.2>98.8< 0		2>98< 0	2>98< 0

TABLE 8—PERCENTAGES OF SUPERIORITY-INFERIORITY—EXCESS OF LEARNING SPAN OVER DIGIT SPAN FOR EACH AGE

Excess of L.S. over D.S.	*4 years*	*5 years*	*6 years*	*7 years*	*8 years*	*9 years*	*10 years*
0	68> 0<32	61> 0<39	47> 0<53	26> 0<74	39 > 0 <61	35 > 0 <65	26 > 0 <74
1	32>68< 0	37>61< 2	48>47< 5	61>26<13	49 >39 <12	47 >35 <18	45 >26 <29
2		2>98< 0	4>95< 1	12>87< 1	10 >88 < 2	13 >82 < 5	25 >71 < 4
3			1>99< 0	1>99< 0	1 >98 < 1	2 >95 < 3	3 >96 < 1
4						1.5>97 < 1.5	
5							
6						.5>98.5< 1	
7					.5>99 < .5	.5>99 < .5	.5>99 < .5
8					.5>99.5< 0	.5>99.5< 0	.5>99.5< 0

TABLE 9—PERCENTAGESOF SUPERIORITY-INFERIORITY—LEARNING SPANS FOR EACH AGE

L.S.	*4 years*	*5 years*	*6 years*	*7 years*	*8 years*	*9 years*	*10 years*
3	13> 0<87	9> 0<91	3> 0<97	1> 0<99	1 > 0 <99		
4	49>13<28	37> 9<44	19> 3<78	9> 1<90	4 > 1 <95	2 > 0 <98	.5> 0 <99.5
5	32>62< 4	31>46<23	29>22<49	29>10<61	26 > 5 <67	21 > 2 <77	14 > .5<85
6	4>94< 2	20>77< 3	27>51<22	37>39<24	36 >31 <23	34 >23 <43	31 >14 <55
7	2>98< 0	3>97< 0	16>78< 6	18>76< 6	16 >67 <17	21 >57 <22	23 >45 <32
8			5>94< 1	4>94< 2	14 >83 < 3	12 >78 <10	17 >68 <15
9			1>99< 0	1>98< 1	1.6>97 < 2.4	7 >90 < 3	10 >85 < 5
10				1>99< 0	1 >98.6< .4	2.5>97 < .5	3.5>95 < 1.5
11							
12							
13					.4>99.6< 0	.5>99.5< 0	1 >98.5< .5
14							
15							.5>99.5< 0
No. Cases Per age	53	118	394	467	252	244	232

TABLE 10—PERCENTAGES OF SUPERIORITY-INFERIORITY—REVERSE DIGIT SPANS

R.D.S.	*6 years*	*7 years*	*8 years*	*9 years*	*10 years*
0	41> 0<59	13> 0<87	3> 0<97	.4> 0 <99.6	
2	26>41<33	21>13<66	11> 3<86	3 > .4<96.6	2 > 0 <98
3	27>67< 6	53>34<13	60>14<26	50 > 3 <47	38 > 2 <60
4	5>94< 1	11>87< 1	23>74< 3	37 >53 <10	42 >40 <18
5	1>99< 0	2>98< 0	3>97< 0	9 >90 < 1	16 >82 < 2
6				1 >99 < 0	1.6>98 < .4
7					.4>99.6< 0

VI. Reverse Digit Span in relation to Digit Span.

Of all children with a Digit Span of 3, 27 per cent earned Reverse Digit Spans;
Of all children with a Digit Span of 4, 69 per cent earned Reverse Digit Spans;
Of all children with a Digit Span of 5, 97 per cent earned Reverse Digit Spans;
Of all children with a Digit Span of 6, 97 per cent earned Reverse Digit Spans;
Of all children with a Digit Span of 7, 99 per cent earned Reverse Digit Spans;
Of all children with a Digit Span of 8, 98 per cent earned Reverse Digit Spans.

Digit Spans 2 and 9 produced reverse digit spans in 100 per cent of their cases but in the former there were only a total of 2 and in the latter a total of 11 cases.

Irrespective of digit span, the reverse digit spans fell as follows: 10 per cent at 0; 13 per cent at 2; 46 per cent at 3; 24 per cent at 4; 6 per cent at 5, and 1 per cent at a reverse span of 6.

VII. Reverse span increases with age.

Reverse spans of 0 decrease with age, i.e., there are 42 per cent of cases at year 6 and 3 per cent of cases at year 9, and 0 per cent of cases at year 10. Reverse spans of 2 are found for 28 per cent of cases at year 6 and 2 per cent of cases at year 10.

The median scores for ages 6 to 10 inclusively fall at reverse digit spans of 2, 3, 3, 3, and 4 respectively.

VIII. The Learning span-age-grade Table shows that:

1. Learning span increases with age.

2. Learning span increases with grade where the children are young for their grade in school, i.e., where an age group has grades I, II, III, and IV in it—an increase in learning span is expected with increasing grade within such age group.

3. The minimum learning span is 3 digits. There were children who fell this low. All were in kindergarten and first grade.

The maximum learning span is 15 digits. There were only 2 children who rated this high. They were in 5th grade.

4. The 60 per cent mode takes in learning spans 5-6-7 irrespective of age and grade.

5. The average size of the learning span increases with age. The nine and ten year old children have no cases at the minimum learning span and only a few cases at the learning span of 4, while two cases fall at the learning span of 15. Most of the nine and ten year cases have a learning span between 5 and 10 digits.

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